

Gordon McKay Laboratory
Harvard University
Cambridge, Massachusetts

Semi-Annual Status Report on

Grant NGR-22-007-056

Theoretical and Experimental Investigations
of Antennas and Waves in Plasma

For the period

March 1, 1967 through September 1, 1967

October 3, 1967

Prepared for
Grants and Research Contracts Division
Office of Space Science and Applications
National Aeronautics and Space Administration
Washington, D. C. 20546

N67-86848

FACILITY FORM 602

(ACCESSION NUMBER)

(THRU)

(PAGES)

(CODE)

(NASA CR OR TMX OR AD NUMBER)

(CATEGORY)

Theoretical and Experimental Studies of Plasma-Coated Antennas - C. Y. Ting
and B. Rama Rao.

An experimental investigation of a plasma-coated finite cylindrical antenna has been completed. The plasma sheath was produced by means of a hot-cathode d.c. discharge contained within a long glass tube. The plasma diagnostic measurements were made by single Langmuir probes and a cavity perturbation method. The current distribution and input admittance of the antenna were measured for wide ranges of discharge currents and pressures. The experimental results show a reasonable degree of qualitative agreement with theory. It is also noticed that the input resistance of a very short dipole shows a strong "resonance" phenomenon at a frequency below the plasma frequency, which may be used as a diagnostic method. Scientific Report, No. 1, entitled "Theoretical and Experimental Study of a Finite Cylindrical Antenna in a Plasma Column" was issued in July, 1967.

Plasma Profile Investigation Using a Microwave Cavity Technique - B. Rama Rao.

A theoretical analysis has been completed to determine the exact eigenfrequencies of a microwave cavity loaded with an inhomogeneous plasma column. The effect of the varying electron density profiles on the resonant frequency of a microwave cavity excited in the TM_{0m1} and TM_{nmo} type modes has been studied by this method. It has been shown that the inhomogeneities in the plasma column cause the cavity modes to become hybrid when the r.f. fields in the cavity have either an axial or azimuthal dependence. At high electron densities the frequency shift becomes very sensitive to the plasma profile variations and accurate measurement of the electron densities cannot be made

by the cavity perturbation technique unless the density distribution in the plasma column is known in detail.

Plasma Diagnostics with Transmission Lines and Cavities - William A. Saxton and Y. S. Yeh.

The construction of the plasma tube and the transmission line has now been completed and both are ready for the planned experiments.

The possibility of diagnosing the properties of the plasma by using a cavity perturbation method in a rectangular cavity with a hole through which the discharge tube protrudes was investigated. This method appears to be useful for plasma diagnostics even though the hole is large compared to critical cavity dimensions. It has the advantage of resolving small portions of the positive column of the discharge. A paper entitled "Perturbation from the Protruding Dielectric in a Microwave Cavity" has been written and submitted for publication.

Brush Cathode Discharges - William A. Saxton

The discharge chamber for testing each of the four pairs of brush cathodes has been completed. Construction was delayed by necessary modifications in the design of the mechanism for axially moving one of the brushes in each pair.

Peripheral equipment for completing the experimental setup, such as the vacuum system, is not all available at this time, but should be incorporated into the project within the next few months. However, since major construction, including the cathodes, has been finished, initial experimental results should appear in the next period.

Acoustic Effects in Plasmas - William A. Saxton.

Most of the effort during this period was directed toward the final design and construction of the experimental setups. The discharge tube for the EM-wave scattering experiment was modified to give a greater flexibility in probing the plasma medium itself. It has now been re-assembled and installed on the appropriate vacuum system. Construction on the acoustic-wave amplification apparatus has been delayed pending the acquisition of a suitable liquid helium dewar for cooling the discharge.

Electromagnetic Scattering from an Acoustically Modulated Plasma Column -
B. Rama Rao and William A. Saxton.

An experimental investigation is being carried out to study the "Bragg type" electromagnetic scattering from an acoustically perturbed plasma column. The acoustic waves inside the plasma column are excited either by means of transducers mounted inside the discharge tube or by means of Langmuir probes connected to an acoustic signal generator. Strong acoustic standing waves are set up within the plasma discharge tube by suitably adjusting the distance between a movable anode and the oxide-coated cathode. The frequency spectrum, angular dependance and scattering amplitudes are being studied. Measurements are being made at 24 GHz.

Experimental Investigations on R. F. Breakdown Effects in Antennas - B. Rama Rao and L. D. Scott.

R. F. breakdown in antennas is frequently encountered by missiles and rockets at high altitudes. The breakdown seriously degrades the vital communi-

cation information such as telemetry and tracking and also causes large changes in the input admittance and radiation pattern of the missile antenna.

The purpose of this investigation is to study the effect of the r.f. breakdown on the near fields of the antenna. The antenna characteristics during breakdown have been investigated as a function of the antenna length, gas pressure and input r.f. power to the antenna. Non-linear phenomena such as the generation of second and third harmonic components of the excitation frequency by the r.f. corona have also been investigated. The power radiated under breakdown conditions and the power absorbed by the r.f. corona surrounding the antenna have been monitored by means of an external probe. Helium gas was chosen for these investigations as its basic electronic processes are well understood, thereby making it easier to interpret the experimental results. The measurements were made under c.w. conditions. These investigations are expected to be completed soon.

A Short Dipole Antenna as a Probe for Plasma Diagnostics - B. Rama Rao and L. D. Scott.

An interesting phenomenon noticed during the course of experimental investigations was the "antiresonant" type of behavior displayed by a short dipole antenna in the vicinity of the plasma frequency. The position and line width of the input resistance curve is determined by the electron plasma frequency and the collision losses of the plasma medium; the input reactance of the antenna also shows an abrupt change in its shape and the coulomb type near field measured by an auxiliary probe also decreases quite sharply in this "resonance" region. A more extensive investigation of this problem is

now underway.

This phenomenon offers the possibility of utilizing the short dipole as a diagnostic tool in ionospheric measurements for measuring the local electron density and collision frequency of the plasma. Another interesting phenomenon under experimental scrutiny now is the 'resonance' type of behavior noticed well above the plasma frequency around $\omega_p/\sqrt{2}$. This phenomenon has been attributed mainly to the ion sheath formed around the antenna. The input admittance of the dipole is being studied as a function of the sheath thickness by applying a varying d.c. bias to the antenna.

Theoretical Studies on the Circular Loop Antenna in a Plasma Environment -
M. Bharathi.

Literature on the circular loop antenna, in free space, dissipative media and magnetoionic media has been surveyed. The problem of radiation from a circular loop antenna immersed in a homogeneous isotropic unbounded warm plasma for the case of constant current distribution around the loop is under investigation.

Theoretical Studies on an Antenna Immersed in a Plasma - A. D. Wunsch.

One important present day use of antennas is in the field of ionospheric exploration. Man-made earth satellites are frequently equipped with dipole antennas which serve as probes to determine the properties of the earth's ionosphere. By measuring the driving-point impedance of such an antenna, information about the medium surrounding the antenna can be obtained.

An article published recently by the author¹ treats the ionosphere as

a cold ionized gas. The antenna, approximated as a strip having a prescribed current distribution, is assumed to be perpendicular to a uniform magnetic field which pervades the gas. An expression has been obtained for the radiation resistance of the antenna in terms of the parameters of the surroundings (magnetic field strength and electron density) and numerical results have been presented for a broad range of operating frequencies. The limitations imposed by treating the antenna as an infinitesimal current element (Hertzian Dipole) are also discussed.

Another aspect of the author's research, briefly described in a recently published note², treats the ionosphere as an isotropic, homogeneous, ionized gas of finite temperature. Unlike the previous problem, no assumption is made concerning the distribution of current along the antenna. The distribution of current along the antenna has been determined and the input resistance and reactance of the antenna thereby obtained. Previous workers have made such warm plasma impedance calculations by using a distribution of current along the antenna which is identical to that which would exist were the plasma cold. The current distributions obtained from the author's analysis show that, in general, this is an unjustified approximation.

✓ The far field radiation pattern of the antenna, based on the correct current distribution, has also been calculated. Since a tubular antenna, driven on the outside and the inside has been considered, it is interesting to determine the relative sizes of the current on the outside and inside of the tube. This is especially important since even a very thin tube containing warm plasma can support an internal propagating wave.

The field pattern results and the analysis of the internal current will

be presented in a longer paper.

- 1 Wunsch, A. D. , "Radiation from a Strip of Electric Current in a Magnetoionic Medium", Canadian Journal of Physics, vol. 45, 1967, pp. 1675-1691.
- 2 Wunsch, A. D. , "Current Distribution on a Dipole Antenna in a Warm Plasma", Electronic Letters, vol. 3, No. 7, July 1967, pp. 320-321.

The staff now supported in part by this grant includes Professor B. Rama Rao, Dr. C. Y. Ting, Dr. William A. Saxton and three part-time students A. D. Wunsch, L. D. Scott and M. Bharathi.

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Submitted by,

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NASA Grant NGR-22-007-056